PATH Experience in Road Vehicle Automation

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Vehicle Control and Automated Driving Research at PATH

- Strong emphasis for 25+ years → over 600 labor years of PATH effort
- Approached from perspectives of vehicle dynamics and control and human factors
  - Deep understanding of mechanical dynamics of vehicles
  - Designing for both high positioning accuracy and smooth ride quality
  - Driver and passenger acceptance based on ride quality and user interfaces
- Experimental verification on full-scale vehicles (20+ passenger cars, 7 heavy trucks, 6 transit buses, 1 snowblower)
Autonomous and Cooperative ITS

Autonomous ITS (Unconnected) Systems

Cooperative ITS (Connected Vehicle) Systems

Automated Driving Systems
Automation is a Tool for Solving Transportation Problems

• Alleviating congestion
  – Increase capacity of roadway infrastructure
  – Improve traffic flow dynamics

• Reducing energy use and emissions
  – Aerodynamic “drafting”
  – Improve traffic flow dynamics

• Improving safety
  – Reduce and mitigate crashes

• Using V2V and I2V connectivity to gain these benefits
PATH Automation Milestones

• 1988 – Basic AHS concepts defined
• 1991 – Hierarchical information architecture
• 1992 – First automated vehicle experiments (4-car longitudinal control platoon, one car automated steering control) and first FHWA funding support
• 1993 – AHS Precursor System Analyses
• 1994-8 – National AHS Consortium (including Demo ’97)
• 1998 – Demo ’98, Netherlands
• 2000 – Demo 2000, Japan
• 2003 – Bus and truck automation demonstrated
• 2007-11 – Mobility Applications for VII project
• 2013 – New CA DMV and FHWA EARP projects
• 2014 – Bus guidance in public service
Key Accomplishments in Automation

• Definition of hierarchical architecture to simplify design and development of automation systems
• Creation of modeling and simulation tools to evaluate system designs and performance
• Development of high-performance automated test vehicles, both light and heavy duty
• Proving feasibility of high-accuracy vehicle control, while maintaining passenger comfort
• Demonstrating that automated driving is pleasant rather than threatening
• Public implementation of bus guidance
Lateral Control (Automatic Steering)

- Many projects over 20+ years
- Extremely high performance systems, exceeding capabilities of human drivers
  - Precision docking bus (within 1 cm)
  - High-g curve following (0.8 g lateral)
  - High-speed reverse driving (>50 km/h)
  - High-speed lane tracking (to 170 km/h)
- Lane referencing from magnetic markers (our invention), DGPS/INS with digital maps, and video image processing
Consistent, Accurate Steering on Highway

- 3 cm lateral variations at every location at highway speeds
Automatic Longitudinal (Platoon) Control

• Engines and brakes of conventionally powered vehicles can be controlled accurately enough for precision vehicle following in platoons (20 cm accuracy)
• Precise vehicle following can be done with smooth ride quality
• Vehicles can be driven in close-formation platoons (3 – 5 m gaps) without exposing occupants to exhaust gases or impeding cooling air to radiators
• Vehicles can merge into the middle of a passing platoon, using wireless coordination
Automated Platoon Longitudinal Control and Merging

1997

2000
Automated Truck Platooning, 2003-11

- Developed and tested 2- and 3-truck platoons under automatic spacing control at gaps from 3 m to 10 m
- All hardware and software implementation by PATH, without industry help
- Fuel savings of 10 -15%
- Current EAR project with Caltrans, Volvo – 3-truck CACC
Cooperative Adaptive Cruise Control (since 2002)

- 3 generations of design, sponsored by Caltrans, FHWA and Nissan
- First-generation system showed driver acceptance of short gap following (0.6 s)
- Second generation showed string stability
- Traffic simulations showed lane capacity doubling potential
- Third generation for STOL Laboratory - 2015
- Current EAR project on CACC string strategies
Other Recent Automation Projects

- International scan of state of development of automation for FHWA EARP helped stimulate U.S. program – 2012 reports
- NCHRP 20-24(98) - AASHTO research roadmap on automation topics for state and local governments - 2014
- Technical support for California DMV in development of state regulations for public use of automated driving systems - ongoing
- Modeling of benefits of adding V2X to automation systems (Toyota ITC) - new